Substitute Specification:

The entire specification (including the abstract) is presented. No changes have been made to the specification.

METHOD FOR IMAGE PROCESSING BY UNSHARP MASKING

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Background of Invention

1. Field of the Invention

10   The present invention relates to a method for adjusting an image signal by a processor, and more specifically, to a method for image processing by unsharp masking.

2. Description of the Prior Art

Please refer to Fig.1 and Fig.2. Fig.1 is a block diagram illustrating a conventional image processing system 10 and Fig.2 illustrates an image 14 of the image processing
15   system 10 in Fig.1. The image processing system 10 includes a memory 12 for storing programs and the image 14 to be processed, and a processor 16 for executing the programs stored in the memory 12. The image 14 includes a plurality of pixels 18 arranged in matrix form. The image 14 is composed of an image area 20 with specific features and a boundary area 22 around the image area 20.

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A goal of image processing is to have the features of the image area 20 stand out while keeping the image area 20 and the surrounding edge area 22 in harmony. An adjustment of the image parameters of the whole image 14 will sacrifice some features that are not within the image area 20 or cause distortion of the image area 20. For this
25   reason, some image processing methods adjust only the image parameters of the surrounding edge area 22 in order to emphasize the high frequency characteristic of the edge of the image.

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The unsharp mask method is a method based on the concept mentioned above. According to the method, first unsharpen an image to obtain a low frequency element of the image, then subtract the unsharpened image from the original image to obtain a high frequency element of the original image. Apply a convolution operation to the remaining

5   high frequency image and eventually add the subtracted low frequency image to the remaining high frequency image to complete the process. Although the unshap mask method can sharpen the edge of the image, it also increases the high frequency element of the image and raises the luminance of the whole image, making it lighter. In addition, according to the conventional unsharp mask method, while applying the convolution

10   operation to the high frequency image and adding back the subtracted low frequency image, because two operation intensive calculations are required to be processed simultaneously, processing time and image processing cost are increased.

Summary of Invention

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It is therefore a primary objective of the present invention to provide a method for adjusting an image signal by a processor to solve the problem mentioned above.

Briefly summarized, a method for adjusting an image signal by a processor includes

20   providing a first low pass filter and a second low pass filter; generating an energy ratio of a band-pass image signal and the image signal according to the standard deviation of the low pass signal of the first low pass filter and the low pass signal of the second low pass filter; providing an image adjustment parameter and generating a weighting coefficient of the image signal according to the energy ratio and the image adjustment parameter;

25   generating a third low pass filter according to the weighting coefficient of the image signal, the image adjustment parameter, the low pass signal of the first low pass filter, and the low pass signal of the second low pass filter; and adjusting the image signal according to the image signal and the third low pass filter.

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These and other objectives of the present invention will no doubt become obvious to those of ordinary skill in the art after reading the following detailed description of the preferred embodiment that is illustrated in the various figures and drawings.

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Brief Description of Drawings

Fig.1 is a block diagram illustrating a conventional image processing system.

Fig.2 illustrates an image of the image processing system in Fig.1.

10 Fig.3 is a block diagram illustrating an image processing system according to the present invention.

Fig.4 illustrates a flowchart of image processing by the image processing system according to the present invention.

Fig.5 illustrates a subtraction between a low pass filter signal $h_1(x,y)$ of the first

15 low pass filter and a low pass filter signal $h_2(x,y)$ of the second low pass filter in frequency domain.

Fig.6 illustrates a flowchart for image processing by an image processing system according to the second embodiment of the present invention.

Fig.7 illustrates a subtraction between the unit pulse signal $\delta(x,y)$ and a low pass

20 filter signal $h_2(x,y)$ of the second low pass filter in frequency domain.

Detailed Description

Please refer to Fig.3. Fig.3 is a block diagram illustrating an image processing

25 system 30 according to the present invention. The image processing system 30 includes a memory 32 for storing an image processing program 34 and an image 36 to be processed. The image processing program 34 includes a first low pass filter 38 and a second low pass

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filter 40 implemented using software. The first low pass filter 38 and the second low pass filter 40 can also be hardware circuits. The image processing system 30 further includes an image processor 42 for executing the image processing program 34 stored in the memory 32, and an input device 44 for image parameter settings.

Please refer to Fig.4 showing a flowchart for image processing by the image processing system 30 according to the present invention. The flowchart in Fig.4 includes following steps:

Step 100: Please refer to Fig.5 showing a subtraction between a low pass filter signal $h_1(x,y)$ of the first low pass filter 38 and a low pass filter signal $h_2(x,y)$ of the second low pass filter 40, shown in frequency domain. Obtain a band-pass filter signal $h(x,y)$ by subtracting the low pass filter signal $h_2(x,y)$ of the second low pass filter 40 from the low pass filter signal $h_1(x,y)$ of the first low pass filter 38. Define the signal resulting from convoluting the band-pass filter signal $h(x,y)$ and an image signal $I(x,y)$ as a band-pass image signal $h(x,y) \otimes I(x,y)$, wherein $\otimes$ means convolution.

Step 102: Generate an energy ratio $\dfrac{E_{h \otimes I}}{E_I}$ of the band-pass image signal and the image signal according to the standard deviation of the low pass filter signal $h_1(x,y)$ of the first low pass filter 38 and the low pass filter signal $h_2(x,y)$ of the second low pass filter 40. The energy ratio $\dfrac{E_{h \otimes I}}{E_I}$ of the band-pass image signal $h(x,y) \otimes I(x,y)$ and the image signal $I(x,y)$ is equivalent to $\dfrac{1}{4\pi\sigma_1^2} - \dfrac{2}{2\pi\left(\sigma_1^2 + \sigma_2^2\right)} + \dfrac{1}{4\pi\sigma_2^2}$ wherein σ_1 is not

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equivalent to σ_2.

Step 104: Provide a maximum image distortion ratio and divide it with the energy

ratio $\dfrac{E_{h\otimes I}}{E_I}$ to obtain a maximum image adjustment weighting coefficient

$C_2|_{max}$. Further provide an image adjustment normalized value between 0

5   and 1 so that an image adjustment parameter C_2 can be obtained by

multiplying the maximum image adjustment weighting coefficient $C_2|_{max}$

with the image adjustment normalized value. A user can input the image

adjustment normalized value by the input device 44 of the image

processing system 30 to obtain the image adjustment parameter C_2.

10   Step 106: Generate a weighting coefficient C_1 of the image signal according to the

energy ratio $\dfrac{E_{h\otimes I}}{E_I}$ and the image adjustment parameter C_2, wherein

$$C_1 = 1 - C_2 \frac{E_{h\otimes I}}{E_I}.$$

Step 108: Obtain a third low pass filter 41 $h_3(x,y)$ according to the weighting

coefficient C_1 of the image signal, the image adjustment parameter C_2,

15   the low pass filter signal $h_1(x,y)$ of the first low pass filter 38, and the

low pass filter signal $h_2(x,y)$ of the second low pass filter 40, wherein

$h_3(x,y) = C_1\delta(x,y) + C_2[h_1(x,y) - h_2(x,y)]$, and $\delta(x,y)$ is a delta

function.

Step 110: Finally, convolute the third low pass filter 41 $h_3(x,y)$ with the image

20   signal $I(x,y)$ to   obtain   an   adjusted   image   signal

$f_1(x,y) = h_3(x,y) \otimes I(x,y)$, wherein $\otimes$ means convolution.

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The image processing method according to the first embodiment of the present invention includes capturing the high frequency portion of the image 36 and applying a convolution operation, i.e. $C_2[h(x,y) \otimes I(x,y)]$. Then adding the weighting coefficient of the original signal, i.e. $C_1 I(x,y)$, so that the high frequency portion can be emphasized.

5   Further imposing a restriction according to conservation of energy, i.e. $\left(E_{f_1} = C_1 E_I + C_2 E_{h \otimes I}\right) \wedge \left(E_{f_1} = E_I\right)$, and calculating an adjusted image signal $f_1(x,y)$ under the condition that the energy of the adjusted image signal $f_1(x,y)$ is equivalent to the energy of the original image signal $I(x,y)$.

10   More specifically, under the condition that a limited signal has the same energy in either time domain and space domain according to the Rayleigh's theorem, calculate the energy ratio $\dfrac{E_{h \otimes I}}{E_I}$ of the band-pass image signal $h(x,y) \otimes I(x,y)$ and the image signal $I(x,y)$, wherein $\dfrac{E_{h \otimes I}}{E_I} = \dfrac{1}{4\pi\sigma_1^2} - \dfrac{2}{2\pi\left(\sigma_1^2 + \sigma_2^2\right)} + \dfrac{1}{4\pi\sigma_2^2}$, σ_1 and σ_2 represent respectively the standard deviations of the low pass filter signal $h_1(x,y)$ of the first low

15   pass filter 38 and the low pass filter signal $h_2(x,y)$ of the second low pass filter 40, and σ_1 is not equivalent to σ_2 so that $\dfrac{E_{h \otimes I}}{E_I}$ will not be zero and the band-pass filter signal $h(x,y)$ can capture the high frequency portion of the image 36. Then obtain $C_1 = 1 - C_2 \dfrac{E_{h \otimes I}}{E_I}$ on the bases that $E_I = C_1 E_I + C_2 E_{h \otimes I}$.

20   Subsequently, while determining the image adjustment parameter C_2 and the weighting coefficient C_1 of the image signal in Step 104 and Step 106, a maximum image distortion ratio must first be determined, that is the maximum acceptable energy

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decay of the unprocessed low frequency portion such as the image area 20 in Fig.2. For instance, if the energy decay of the image area of the image 36 is to be limited to 5%, the minimum weighting coefficient of the image signal can be determined as $C_1|_{min} = 1 - 0.05 = 0.95$ and the maximum image adjustment weighting coefficient can be

5   determined as $C_2|_{max} = \dfrac{0.05}{E_{h\otimes I}/E_I}$. For the user's convenience, it is possible to provide the image adjustment normalized value between 0 and 1 normalized from the image adjustment parameter C_2 by the input device 44 of the image processing system 30 so that the image adjustment parameter C_2 can be obtained by multiplying the maximum image adjustment weighting coefficient $C_2|_{max}$ with the image adjustment normalized

10   value. That is, when a user inputs 1 as the normalized value by the input device 44, the image adjustment parameter C_2 is $\dfrac{0.05}{E_{h\otimes I}/E_I}$, the weighting coefficient C_1 of the image signal is 0.95, and the adjusted energy amplitude will be 5% in maximum. Alternatively, when the user inputs 0 as a corresponding weighting coefficient by the input device 44, the image adjustment parameter C_2 is 0, the weighting coefficient C_1 of the image signal is 1, and the adjusted energy amplitude will be 0% in minimum,

15   which means not to adjust the image 36.

Continuously evaluate the third low pass filter 41 $h_3(x,y)$ using the first filter 38, the second filter 40, the above-mentioned C_1 and C_2, and the equation

20     $h_3(x,y) = C_1\delta(x,y) + C_2[h_1(x,y) - h_2(x,y)]$, wherein $\delta(x,y)$ is a unit pulse signal. Convolute the third low pass filter 41 and the image signal to obtain the adjusted image signal $f_1(x,y) = h_3(x,y) \otimes I(x,y)$. In such a way the luminance change in the prior art can be improved.

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Please refer to Fig.6 showing a flowchart for image processing by an image processing system 30 according to the second embodiment of the present invention. The difference between the two embodiments is that in the second embodiment, to simplify the calculation, a second low pass filter 40 and a unit pulse signal are used instead of the first low pass filter 38. However, when inputting an image adjustment value, the second embodiment will not show a linear transition as in the first embodiment. The flowchart in Fig.6 includes following steps:

Step 112: Please refer to Fig.7 showing a subtraction between the unit pulse signal $\delta(x,y)$ and a low pass filter signal $h_2(x,y)$ of the second low pass filter 40 in frequency domain. Determine a high pass filter signal $h'(x,y)$ obtained by subtracting the low pass filter signal $h_2(x,y)$ of the second low pass filter 40 from the low pass filter signal $h_1(x,y)$ of the first low pass filter 38. Define the signal resulted by convoluting $h'(x,y)$ and an image signal $I(x,y)$ as a high pass image signal $h'(x,y) \otimes I(x,y)$.

Step 114: Generate an energy ratio $\frac{E_{h'\otimes I}}{E_I}$ of the high pass image signal and the image signal according to the standard deviation of the low pass filter signal $h_2(x,y)$ of the second low pass filter 40. The energy ratio $\frac{E_{h'\otimes I}}{E_I}$ of the high pass image signal $h'(x,y) \otimes I(x,y)$ and the image signal $I(x,y)$ is equivalent to $1 - \frac{3}{4\pi\sigma_2^2}$, wherein σ_2 is larger than $\sqrt{\frac{3}{4\pi}}$.

Step 116: Provide a maximum image distortion ratio and divide it with the energy ratio $\frac{E_{h'\otimes I}}{E_I}$ to obtain a maximum image adjustment weighting coefficient

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$C_4|_{max}$. Further provide an image adjustment normalized value between 0 and 1 so that an image adjustment parameter C_4 can be obtained by multiplying the maximum image adjustment weighting coefficient $C_4|_{max}$ with the image adjustment normalized value. A user can input the image adjustment normalized value using an input device 44 of the image processing system 30 to obtain the image adjustment parameter C_4.

Step 118: Generate a weighting coefficient C_3 of the image signal according to the energy ratio $\dfrac{E_{h'\otimes I}}{E_I}$ and the image adjustment parameter C_4, wherein

$$C_3 = 1 - C_4 \frac{E_{h'\otimes I}}{E_I}.$$

Step 120: Obtain a fourth low pass filter 46 $h_4(x,y)$ according to the weighting coefficient C_3 of the image signal, the image adjustment parameter C_4, and the low pass filter signal $h_2(x,y)$ of the second low pass filter 40, wherein $h_4(x,y) = C_3\delta(x,y) + C_4[\delta(x,y) - h_2(x,y)]$ and $\delta(x,y)$ is the unit pulse signal.

Step 122: Convolute the third low pass filter 46 $h_4(x,y)$ and the image signal $I(x,y)$ to obtain an adjusted image signal $f_2(x,y) = h_4(x,y) \otimes I(x,y)$.

The image processing method according to the second embodiment is essentially the same to that of the first embodiment. The method is to capture the high frequency portion of the image 36 and apply a convolution operation, i.e. $C_4[h'(x,y) \otimes I(x,y)]$, then add the weighting coefficient of the original signal, i.e. $C_3 I(x,y)$, so that the high frequency portion is emphasized. Additionally, impose a restriction according to the conservation of energy, i.e. $\left(E_{f_2} = C_3 E_I + C_4 E_{h'\otimes I}\right) \wedge \left(E_{f_1} = E_I\right)$, and calculate an adjusted image signal

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$f_2(x,y)$ under the condition that the energy of the adjusted image signal $f_2(x,y)$ is equivalent to the energy of the original image signal $I(x,y)$.

In the same manner, under the condition that a limited energy signal has the same energy in either time domain or space domain according to the Rayleigh's theorem, calculate the energy ratio $\dfrac{E_{h'\otimes I}}{E_I}$ of the high pass image signal $h'(x,y)\otimes I(x,y)$ and the image signal $I(x,y)$, wherein $\dfrac{E_{h'\otimes I}}{E_I}=1-\dfrac{3}{4\pi\sigma_2^2}$, and σ_2 is larger than $\sqrt{\dfrac{3}{4\pi}}$ so that $\dfrac{E_{h'\otimes I}}{E_I}$ will be larger than zero, in other words, the band-pass filter signal $h'(x,y)\otimes I(x,y)$ is able to capture the high frequency portion of the image 36. Since the flowchart of the second embodiment is similar to that of the first embodiment, further description is hereby omitted.

In contrast to the prior art, the present invention is capable of sharpening the edge of an image while maintaining the luminance, so that the disadvantage of the prior art which makes the image lighter due to the increased high frequency portion can be improved. Additionally, in contrast to the operation intensive calculations caused by twice adjustments on image signals required by the prior art, the method according to the present invention only calculates weighted parameters and filter signals in space domain first. In such a manner the operations are reduced and, accordingly, the cost and time of image processing is reduced at the same time.

Those skilled in the art will readily observe that numerous modifications and alterations of the device may be made while retaining the teachings of the invention. Accordingly, the above disclosure should be construed as limited only by the metes and

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bounds of the appended claims.

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